Incidence of Descending Aortic Pathology and Evaluation of the Impact of Thoracic Endovascular Aortic Repair: A Population-based Study in England and Wales from 1999 to 2010

R.S. von Allmen *, A. Anjum, J.T. Powell

Vascular Surgery Research Group, Imperial College, Charing Cross Campus, St Dunstan's Road, London W6 8RF, UK

WHAT THIS PAPER ADDS?

The impact of thoracic aortic endovascular repair (TEVAR) on vascular surgical practice and workload has not been assessed previously. Using routine data, this paper shows an escalating use of TEVAR for repair of descending thoracic aortic dissections and aneurysms, in the absence of any known benefit of TEVAR on patient survival.

Objectives: To investigate population trends in thoracic aortic disease (dissections and aneurysms) in England and Wales, with focus on the impact of thoracic endovascular aortic repair on procedure numbers and age at repair.

Materials and methods: Routine hospital statistics of England and Wales provided admission, procedure and mortality data from 1999 to 2010. All data were age-standardised, reported per 100,000 population, by age bands (>50 years or 50–74 years versus 75+ years) and gender. Only patients 50+ years were included, to focus on degenerative disease.

Results: Between 1999 and 2010 hospital admissions for total (ascending and descending) have risen steadily for thoracic aortic dissection (TAD) from 7.2 to 8.8 and thoracic aortic aneurysm (TAA) from 4.4 to 9.0, principally attributable to increased admissions in those 75+ years. Total mortality declined steadily over the same period, for TAD from 4.4 to 3.2 and for TAA from 10.4 to 7.5. Procedure rates have risen sharply, driven by the implementation of TEVAR from 2006, for type B dissection from 0.06 to 0.53 and for descending TAA from 0.76 to 1.89. All figures are per 100,000 population with $P < 0.005$.

Conclusion: Improvements in case ascertainment may have contributed to the increase in hospital admissions. The increased application of TEVAR, particularly for dissections, is mainly in those above 75 years and has not yet translated into an accelerated survival benefit.

Article history: Received 14 September 2012, Accepted 10 December 2012, Available online 29 December 2012

Keywords: Thoracic aortic aneurysm, Aortic dissection, Incidence, Endovascular aortic repair

INTRODUCTION

Degenerative aneurysms develop throughout the aorta. The incidence and prevalence rates of abdominal aortic aneurysms (AAA), the commonest aortic aneurysm, have been assessed more widely than those for thoracic aortic aneurysms (TAA), thoracoabdominal aneurysms or thoracic aortic dissections (TAD). Far less is known about the incidence, prevalence and natural history of thoracic aortic pathology, which previously has been far less common than abdominal aneurysm. Recent improvements in thoracic imaging, with widespread application, are likely to lead to a continuing increase in case ascertainment of TAA.[1]

Very recently, screening studies from different parts of the world have shown a substantial decrease of AAA prevalence to less than 2% in men aged ≥65 years and there is evidence that the incidence of ruptured aneurysm and mortality from AAA also are declining.[2–4] Screening programmes were implemented too late to explain these decreases and the reasons for change are multifactorial, including the introduction of endovascular repair and risk factor management, particularly the rapidly declining proportion of the older population who continue to smoke.[5] In addition, the disease burden for abdominal aortic aneurysm has shifted to the oldest age group (≥75 years).

* Corresponding author. R.S. von Allmen, Vascular Research Group, Charing Cross Hospital, St Dunstan's Road, London W6 8RP, UK. Tel.: +44 20233117316; fax: +44 20233117330.

E-mail addresses: r.von-allmen@imperial.ac.uk (R.S. von Allmen), regula.vonallmen@insel.ch (R.S. von Allmen).

1078-5884/$ — see front matter

http://dx.doi.org/10.1016/j.ejvs.2012.12.007

Similarly, the age standardised mortality for myocardial infarction has fallen by almost half between 2002 and 2010, due to a decline in event rate as well as improved survival.[6]

For TAA, incidence and prevalence studies are scarce and data are rarely separated into ascending and descending aortic pathologies, even though the treatment options and outcomes vary considerably according to anatomical location and pathology of the disease. Various studies since the early 1980s have indicated an increase in the incidence rate of thoracic disease, though each study focused on assessing a different thoracic aortic pathology.[1,7,8] At the beginning of the 21st century, open surgical repair was the default corrective procedure for TAA and occasionally used for TAD. Since then, thoracic endovascular repair (TEVAR) has been implemented and evaluated in device registries[9–11] with its use becoming widespread, particularly for the management of descending aortic disease. Nevertheless, there is evidence that TEVAR may be used in older and frailer patients, without any survival benefit.[12]

The aim of this study is to determine and investigate recent hospital trends and mortality from thoracic aortic disease (both TAA and TAD) in England and Wales.

METHODS

Routine hospital data from 1999 to 2010 were provided by Hospital Episodes Statistics (HES) (England) and Health Solutions Wales PEDW Statistics (Wales). The HES database is a record level database of hospital admissions in English National Health Service (NHS) hospitals. Data years run from April of the named year to March of the following year.

Mortality data were obtained for England and Wales from 1979 to 2010, from the UK Office for National Statistics, which gather all death data of residents in England and Wales. Data years run from January to December of the named year. The diagnoses/mortality codes used were obtained from the tenth revision of the International Classification of Diseases (ICD 10). These were; dissection of aorta (I71.0); thoracic aortic aneurysm ruptured (I71.1); thoracic aortic aneurysm without mention of rupture (I71.2). Codes for thoracoabdominal aortic aneurysm ruptured (I71.5) and thoracoabdominal aortic aneurysm without mention of rupture (I71.6) were not included. Mortality covers all mortality, without separation of whether this is in or out of hospital.

Data for hospital procedures were also obtained from Hospital Episode Statistics and Health Solutions Wales PEDW Statistics, for England and Wales respectively. These are coded according to the fourth revision of the Classification of Interventions and Procedures (OPCS-4), and were used to identify thoracic aortic repairs (Tables 1a and 1b). Ascending aortic procedural codes were included to calculate total thoracic aortic admissions and mortality, since TAA and TAD admissions and mortality data are not available separated by ascending and descending codes. All abdominal aortic aneurysm codes were excluded from mortality, hospital episodes and procedures data. Aneurysm of unspecified sites also were excluded as aortic aneurysm of unspecified site tends to be at the abdominal site.[13]

Age and sex specific population based mortality, hospital admissions and procedures were used to calculate age-standardised mortality, admission and procedure rates at each yearly interval. All data were age-standardised, reported per 100,000 population, by age bands (≥50 years, 50–74 years and ≥75 years) and by gender. Only patients aged 50 years and above were included in order to focus on patients with degenerative disease and minimise the numbers with connective tissue disorders. The number of deaths, admissions and procedures were used as the numerators and the total corresponding age thresholds were used as the denominators to calculate deaths, admissions and procedures per 100,000 population.

Trends in different age bands and gender were assessed by linear regression analysis using the Comprehensive R Archive Network. An alpha level of 0.05 was chosen to determine statistical significance of differences.

Table 1a. Procedural codes for thoracic aortic aneurysms.

L18.2	Emergency replacement aneurysmal segment of thoracic aorta
L19.2	Other replacement of aneurysmal segment of thoracic aorta
L27.3	Endovascular insertion of stent graft for thoracic aortic aneurysm
L28.3	Endovascular stenting for thoracic aortic aneurysm

Table 1b. Procedural codes for thoracic aortic dissections.

L20.2	Emergency bypass of segment of thoracic aorta
L21.2	Bypass of segment of thoracic aorta
L27.4	Endovascular insertion of stent graft for aortic dissection
L28.4	Endovascular stenting for aortic dissection

RESULTS

Mortality trends

The age-standardised mortality was estimated for TAA and TAD in England and Wales from 1979 to 2010. A modest

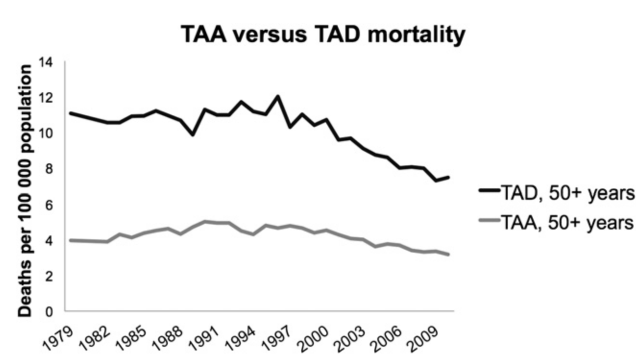

Figure 1. Age standardised mortality for thoracic aortic aneurysm (solid grey line) and thoracic aortic dissection (solid black line) in England and Wales 1979–2010, by gender. Data were standardised from above the age of 50 years for total deaths of ICD9/10 codes; 441.1,2/I71.1,2 (TAA) and 441.0/I71.0 (TAD).

increase in mortality was observed until 1996 for both TAD and TAA and there was a significant decline thereafter, the decline being more marked for TAD (Fig. 1). Since 1999 (the first year of hospital admissions and procedures reporting), age standardised mortality for TAD has decreased steadily from 10.39 to 7.47 ($P < 0.0001$) and for TAA from 4.39 to 3.18 ($P < 0.0001$) deaths per 100,000 population. The rate of decline in mortality for both TAA and TAD was similar in men and women. For TAA, in men mortality declined from 3.7 to 2.3 ($P < 0.0001$) and in women from 5.0 to 3.9 ($P < 0.0001$) per 100,000 population. For TAD, in men mortality declined from 10.0 to 7.0 ($P < 0.0001$) and in women from 10.8 to 7.9 ($P < 0.0001$) per 100,000 population.

Admissions 1999—2010

The age-standardised admissions for TAA from 1999 to 2010, separated into ruptures and non-rupture admissions, are shown by age bands in Fig. 2. Overall hospital admissions have risen from 4.4 to 9.0 ($P < 0.0001$). Whilst the rate of emergency admissions for rupture has changed little, there has been a steady increase in admissions for intact aneurysm since 2001, particularly among those 75+ years of age.

Age-standardised admissions for TAD have risen from 7.2 to 8.8 per 100,000 population ($P = 0.0001$) over the same period (Fig. 3).

For TAA, the increase in admissions was similar in men (5.5—10.8, $P < 0.0001$), and women (3.4—7.4, $P < 0.0001$) per 100,000 population respectively. For TAD, the increase in admissions also was similar for men and women, men from 10.1 to 12.2 ($P = 0.023$) and women from 4.7 to 5.8 ($P = 0.0002$) per 100,000 population.

Descending aortic repairs

Procedure codes permit the separation of repairs for ascending and descending aortic disease. Since the separate coding of open repair and TEVAR from 2006 forward, the rate of repairs for descending TAA has more than doubled. In 2005, the overall rate of repairs was 0.7 versus 1.9 per 100,000 population in 2010. The most marked increase has been in those aged 75+ years (Fig. 4). Whilst the rate of open repairs has been fairly steady, the increases are entirely attributable to the increased rate of TEVAR (Fig. 4).

The changes for type B aortic dissection are even more remarkable. Overall, repairs have increased from 0.1 in 2000 to 0.5 per 100,000 population ($P = 0.0001$) in 2010. Again, the most accentuated changes have been in those 75+ years, where rates of repair have increased about 30-fold (Fig. 5).

For TAA, both men and women have benefited similarly from the increased rate of TEVAR (Fig. 6). TEVAR procedures have risen since 2006 from 0.65 to 1.71 ($P = 0.001$) and from 0.24 to 0.83 ($P = 0.004$) per 100,000 population in men and women, respectively.

In contrast, for TAD, men tend to have benefited more than women from the increased application of TEVAR (Fig. 6). Since 2006 TEVAR procedures for TAD have increased in men from 0.31 to 0.83 per 100,000 population ($P = 0.072$) and in women from 0.13 to 0.17 per 100,000 population ($P = 0.339$).

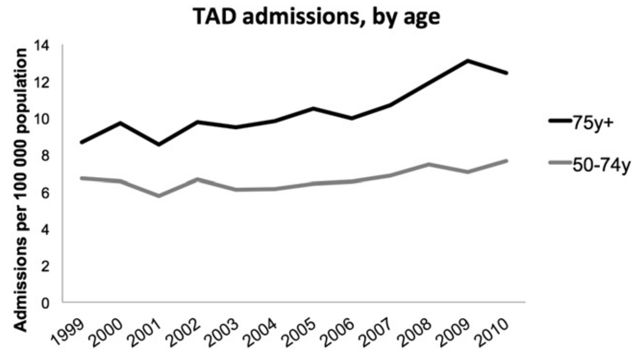

Figure 3. Admissions for thoracic aortic dissection in England and Wales 1999—2010, by age. TAD admissions; 50—74 years (solid grey line), 75+ years (solid black line). Data were standardised by age group for ICD 10 codes; I71.0 (dissection of aorta, any part).

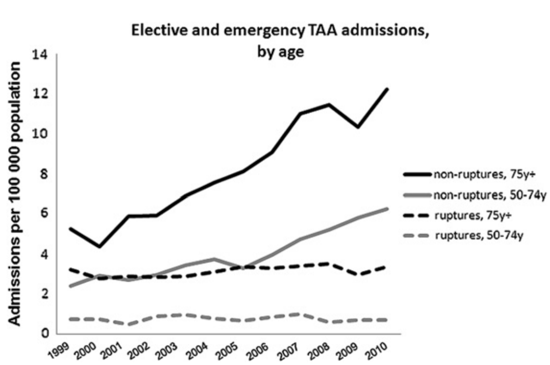

Figure 2. Admissions for non-ruptured and ruptured thoracic aortic aneurysm in England and Wales 1999—2010, by age. Non-ruptured TAA admissions; 50—74 years (solid grey line), 75+ years (solid black line), ruptured TAA admissions 50—74 years (dashed grey line), 75+ years (dashed black line). Data were standardised from above the age of 50 years separated by the following ICD 10 codes; I71.1 (ruptured TAA) and I71.2 (non-ruptured TAA).

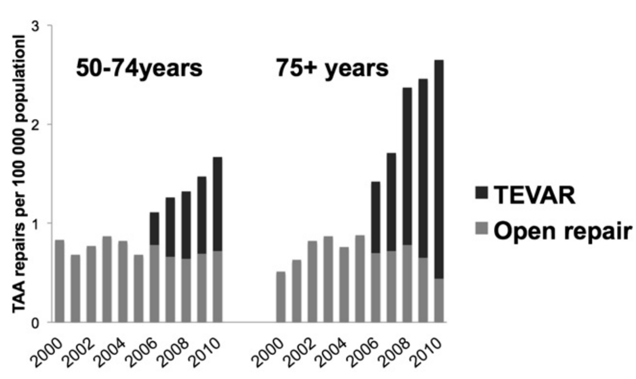

Figure 4. Repairs for descending thoracic aortic aneurysm in England and Wales 1999—2010, by age. TAA open repairs (solid grey bars) and TEVARs (solid black bars); 50—74 years on the left hand side and 75+ years on the right hand side. Data were standardised by age group for procedural codes; L18.2, L19.2, L20.2, L21.2 (open repair), L27.3, L28.3 (TEVAR).

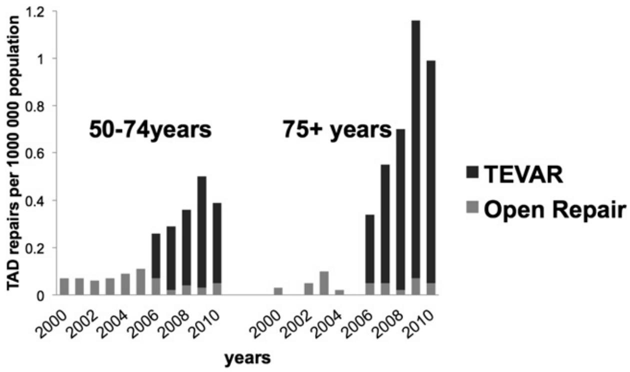

Figure 5. Repairs for descending thoracic aortic dissection in England and Wales 1999–2010, by age. TAD open repairs (solid grey bars) and TEVARs (solid black bars); 50–74 years on the left hand side and 75+ years on the right hand side. Data were standardised by age group for procedural codes; L20.2, L21.2 (open repair), L27.4, L28.4 (TEVAR).

DISCUSSION

This century, mortality from thoracic aortic diseases has been declining, shadowing the trend of other cardiovascular diseases such as myocardial infarction and abdominal aortic aneurysm.[2,3,6,14,15] In contrast, population hospital admission rates have been rising steadily, particularly among those 75+ years of age. The most notable change is the rapid increase in descending aortic repairs since the introduction of TEVAR, particularly for type B aortic dissections. One direct interpretation of these figures is that increased admission and procedure rates are incurring an increased cost burden for the care of thoracic aortic disease.

Mortality for both aneurysm and dissection is decreasing steadily, however the decrease started well ahead of implementation of TEVAR and does not appear to have been accelerated by the rapid rise of TEVAR procedures. It is very likely that the underlying decline in mortality is associated with improvements in management of cardiovascular risks, in line with trends for other cardiovascular diseases, i.e. abdominal aortic aneurysm and myocardial infarction.[6,13]

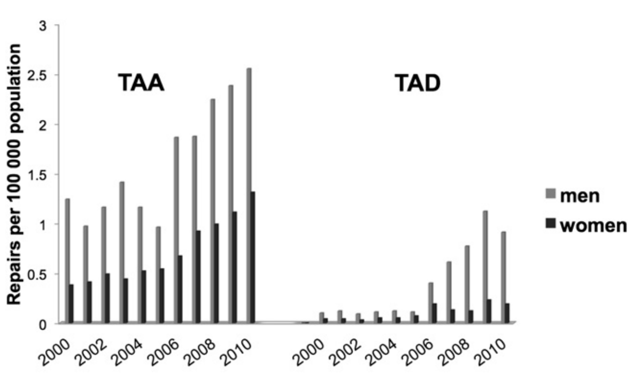

Figure 6. Total repairs for descending thoracic aortic aneurysm (left hand side) and descending thoracic aortic dissection (right hand side) in England and Wales 1999–2010, by gender. Men (solid grey bars), women (solid black bars). Data were standardised by gender for procedural codes; L18.2, L19.2, L20.2, L21.2, L27.3, L28.3 (TAA) and L20.2, L21.2, L27.4, L28.4.

Coroner post-mortem rates in England and Wales (which review all sudden deaths) have remained unchanged during the recent period of study,[16] hence mortality data are unlikely to have been influenced significantly by changes in cause of death ascertainment.

Since admission reporting started in 1999, admissions for both TAA and TAD have been increasing, with an almost 2-fold increase for TAA. This increase in admission rates preceded the implementation of TEVAR by several years. TAA are in most cases asymptomatic and diagnosis is dependent on computerised tomography, cardiac ultrasound or magnetic resonance imaging. Today, computerised tomography of the thorax is widely used in clinical settings, to contribute to an increasing incidental detection rate of asymptomatic aortic aneurysms.[1] Probably, this increase in ascertainment rate has translated into the observed increased in admission rates for TAA. Conversely, patients suffering from TAD most often present with clinical symptoms leading to diagnosis. Hence, case ascertainment is not as important an issue as is for TAA, so that the increase in admission rate has been less marked for TAD than TAA.

A large nationwide population-based Swedish study of aneurysm and dissection of the ascending and descending aorta suggested an increase in incidence rate of thoracic aortic disease since 1987, from 10.7 per 100,000 per year to 16.3 per 100,000 per year in 2002. This increase in incidence was associated with an increase in aortic repairs, initially the increase in thoracic aortic repairs was slow and only accelerated from 1996 onwards.[1] It is important to note that probably very few subjects in this Swedish study underwent TEVAR procedures, since 2002 was before the publication of first TEVAR device validation studies in 2004–2006.[11,17–20] Population-based data about TAA and TAD are scarce and no other up-to-date population-based study has been published covering the time since the more widespread implementation of TEVAR.

This study in England and Wales shows a meteoric increase in procedure rates for descending aortic disease, particularly for TAD, driven by the use of TEVAR. The increase in repairs was most marked in the oldest age group, those 75+ years, with a 3-fold increase for TAD and an almost 2-fold increase for TAA procedures. The treatment burden for thoracic aortic aneurysm and dissections appears to have shifted apparently to the oldest age group, as has been observed for abdominal aortic aneurysm.[13] Although mortality is not separated into ascending versus descending pathologies, the increase in TEVAR procedures does not appear to have accelerated the steady underlying trend of decreasing mortality. Given the current findings, in the future we plan to proceed to analyse linked data, in which mortality, co-morbidities, admission and procedure data are joined to assess the specific effects of TEVAR on mortality. This will permit reporting of in-hospital mortality and mortality rates after either open or endovascular repair.

The present routine data for England and Wales do not reveal the impact of frailty on procedures and procedural mortality. However, there is recent evidence that the existence of several co-morbidities predicts a high one-year mortality after TEVAR, beyond the peri-operative period.[21] Moreover, Medicare data suggest that patients selected for TEVAR have even worse mid-term survival than patients selected for open repair and this difference remained robust even after applying a propensity score matched method aimed at providing unbiased estimates of treatment effects.[12] Consequently, patient selection seems to be the determining factor, particularly for mid- and long-term outcomes following TEVAR.

This study has several limitations, which need to be highlighted. First, available mortality and admission data are based on ICD9/10-codes and therefore the data are not separable by descending and ascending aortic disease. Second, endovascular procedures are not coded as elective or urgent cases nor with regard to localisation (ascending versus descending aorta); however for thoracic aortic aneurysms urgent cases are likely to be less than 5% of the total and the number of endovascular repairs for ascending aortic pathologies remain few. Third, procedures for dissections do not indicate the urgency of the procedure. Fourth, current data are not linked to individual patients; the ratio of admissions to repairs is difficult to interpret. Last, coding errors are inherent in population-based studies and may introduce specific confounders into the analysis.

Nevertheless, the changing trends for admissions and procedures are apparent and these figures implicate a great increase in future vascular workload. Furthermore, the endovascular techniques, which have broadened the vascular armamentarium, also challenge education and training requirements in vascular surgery.

Finally, it is important to realise that TEVAR, unlike endovascular repair of abdominal aortic aneurysm, is still a practice without a solid evidence base. There are a few randomised controlled trials aimed at understanding the role of TEVAR for aortic dissections, but there are none for thoracic aortic aneurysms. The Investigation of Stent Grafts in Aortic Dissection (INSTEAD) trial comparing TEVAR with optimum medical management in uncomplicated sub-acute to chronic type B aortic dissections, turned out to be slightly underpowered and there was no difference between the groups in survival at 2 years.[22] However, there was a steady trickle of conversion to TEVAR in the medical therapy group and the tone of recent presentations suggest that there may be a survival benefit for the TEVAR group after 5 years. Another trial, the ADSORB trial aims at comparing TEVAR and best medical therapy to best medical therapy alone in acute uncomplicated type B aortic dissections. However, this trial focuses only on surrogate endpoints, such as false lumen thrombosis, aortic rupture, and aortic dilatation at one year and no reliable information regarding survival can be expected.[23]

In conclusion, the rapidly escalating rate of thoracic aortic repairs, in the absence of high-level evidence for the mid-term efficacy of TEVAR, calls for a randomised controlled trial focussing on survival and full health economic evaluation.

FUNDING

Camelia Botnar Arterial Research Foundation.

CONFLICT OF INTEREST

None.

REFERENCES

1 Olsson C, Thelin S, Stahle E, Ekbom A, Granath F. Thoracic aortic aneurysm and dissection: increasing prevalence and improved outcomes reported in a nationwide population-based study of more than 14,000 cases from 1987 to 2002. Circulation 2006;114:2611–8.

2 Sandiford P, Mosquera D, Bramley D. Trends in incidence and mortality from abdominal aortic aneurysm in New Zealand. Br J Surg 2011;98:645–51.

3 Anjum A, Powell JT. Is the incidence of abdominal aortic aneurysm declining in the 21st century? Mortality and hospital admissions for England & Wales and Scotland. Eur J Vasc Endovasc Surg 2012;43:161–6.

4 Norman PE, Spilsbury K, Semmens JB. Falling rates of hospitalization and mortality from abdominal aortic aneurysms in Australia. J Vasc Surg 2011;53:274–7.

5 *British Heart Foundation. Heart Statistics Publications*. http://www.bhf.org.uk/heart-health/statistics/heartstatistics-publications.aspx [accessed 01.08.11].

6 Smolina K, Wright FL, Rayner M, Goldacre MJ. Determinants of the decline in mortality from acute myocardial infarction in England between 2002 and 2010: linked national database study. Br Med J 2012;344:d8059.

7 Bickerstaff LK, Pairolero PC, Hollier LH, Melton LJ, Van Peenen HJ, Cherry KJ, et al. Thoracic aortic aneurysms: a population-based study. Surgery 1982;92:1103–8.

8 Clouse WD, Hallett Jr JW, Schaff HV, Gayari MM, Ilstrup DM, Melton 3rd LJ. Improved prognosis of thoracic aortic aneurysms: a population-based study. J Am Med Assoc 1998;280:1926–9.

9 Fairman RM, Criado F, Farber M, Kwolek C, Mehta M, White R, et al. Pivotal results of the Medtronic Vascular Talent Thoracic Stent Graft System: the VALOR trial. J Vasc Surg 2008;48:546–54.

10 Matsumura JS, Cambria RP, Dake MD, Moore RD, Svensson LG, Snyder S, et al. International controlled clinical trial of thoracic endovascular aneurysm repair with the Zenith TX2 endovascular graft: 1-year results. J Vasc Surg 2008;47:247–57 [discussion 57].

11 Makaroun MS, Dillavou ED, Kee ST, Sicard G, Chaikof E, Bavaria J, et al. Endovascular treatment of thoracic aortic aneurysms: results of the phase II multicenter trial of the GORE TAG thoracic endoprosthesis. J Vasc Surg 2005;41:1–9.

12 Goodney PP, Travis L, Lucas FL, Fillinger MF, Goodman DC, Cronenwett JL, et al. Survival after open versus endovascular thoracic aortic aneurysm repair in an observational study of the Medicare population. Circulation 2011;124:2661–9.

13 Anjum A, von Allmen R, Greenhalgh R, Powell JT. Explaining the decrease in mortality from abdominal aortic aneurysm rupture. Br J Surg 2012;99:637–45.

14 Schmidt M, Jacobsen JB, Lash TL, Botker HE, Sorensen HT. 25 year trends in first time hospitalisation for acute myocardial infarction, subsequent short and long term mortality, and the prognostic impact of sex and comorbidity: a Danish nationwide cohort study. Br Med J 2012;344:e356.

15 Bandosz P, O'Flaherty M, Drygas W, Rutkowski M, Koziarek J, Wyrzykowski B, et al. Decline in mortality from coronary heart disease in Poland after socioeconomic transformation: modelling study. Br Med J 2012;344:d8136.

16 Pounder D, Jones M, Peschel H. How can we reduce the number of coroner autopsies? Lessons from Scotland and the Dundee initiative. J R Soc Med 2011;104:19—24.
17 Greenberg RK, O'Neill S, Walker E, Haddad F, Lyden SP, Svensson LG, et al. Endovascular repair of thoracic aortic lesions with the Zenith TX1 and TX2 thoracic grafts: intermediate-term results. J Vasc Surg 2005;41:589—96.
18 Stone DH, Brewster DC, Kwolek CJ, Lamuraglia GM, Conrad MF, Chung TK, et al. Stent-graft versus open-surgical repair of the thoracic aorta: mid-term results. J Vasc Surg 2006;44:1188—97.
19 Leurs LJ, Bell R, Degrieck Y, Thomas S, Hobo R, Lundbom J, et al. Endovascular treatment of thoracic aortic diseases: combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. J Vasc Surg 2004;40:670—9 [discussion 9—80].
20 Fattori R, Nienaber CA, Rousseau H, Beregi JP, Heijmen R, Grabenwoger M, et al. Results of endovascular repair of the thoracic aorta with the talent thoracic stent graft: the Talent Thoracic Retrospective Registry. J Thorac Cardiovasc Surg 2006;132:332—9.
21 Scali ST, Chang CK, Feezor RJ, Hess Jr PJ, Beaver TM, Martin TD, et al. Preoperative prediction of mortality within 1 year after elective thoracic endovascular aortic aneurysm repair. J Vasc Surg 2012;2012(56):1266—73.
22 Nienaber CA, Rousseau H, Eggebrecht H, Kische S, Fattori R, Rehders TC, et al. Randomized comparison of strategies for type B aortic dissection: the INvestigation of STEnt Grafts in Aortic Dissection (INSTEAD) trial. Circulation 2009;120: 2519—28.
23 Brunkwall J, Lammer J, Verhoeven E, Taylor P. ADSORB: a study on the efficacy of endovascular grafting in uncomplicated acute dissection of the descending aorta. Eur J Vasc Endovasc Surg 2012;44:31—6.